Volume Title: Output, Employment, and Productivity in the United States after 1800

Volume Author/Editor: Dorothy S. Brady, ed.

Volume Publisher: NBER

Volume ISBN: 0-870-14186-4

Volume URL: http://www.nber.org/books/brad66-1

Publication Date: 1966

Chapter Title: Machine Tool Output, 1861-1910

Chapter Author: Duncan McDougall

Chapter URL: http://www.nber.org/chapters/c1576

Chapter pages in book: (p. 497 - 522)

Machine Tool Output, 1861–1910

DUNCAN M. McDOUGALL
CARLETON UNIVERSITY

Introduction

A quantitative study of the American machine tool industry in the latter half of the nineteenth century faces a data problem of formidable proportions. This results not only from the lack of statistical information, common to many areas of research of that period, but primarily from the fact that it was not until the end of the period that a distinct machine tool industry emerged in the sense of a group of firms whose principal product was machine tools. Until about 1900, the machine tool industry could not be called a large, independent sector of the economy like many of the other groups of companies that led in American industrialization.

A reading of the classic work by Roe on the early American machine tool manufacturers gives the opposite impression.[1] A whole chapter is devoted to Joseph Brown and the Brown and Sharpe Manufacturing Company of Providence, Rhode Island, as one of the leading New England machine tool companies. Founded on the invention of the universal milling machine and the precision devices invented and produced by Brown, Brown and Sharpe was undoubtedly a leading company. On the other hand, examination of the financial records of the company reveals that the value of its output of sewing machines, manufactured under license from Wilcox and Gibbs, exceeded the value of machine tool shipments until 1885, twenty-five years after the invention of the universal milling machine. The year 1898 was the first in which the value of machine tool shipments accounted for more than 50 per cent of the total sales of Brown and Sharpe and, although that percentage was approached in

NOTE: The author wishes to acknowledge financial assistance from the Ford Foundation, the Interuniversity Committee on American Economic History, and Purdue University; the cooperation of many persons in the machine tool industry; and the assistance of George A. Wing and Arvid M. Zarley; all of whom contributed greatly to this paper, but none of whom are responsible for the conclusions, opinions, or statements contained herein. That responsibility remains the author's alone.

[1] J. W. Roe, *English and American Tool Builders*, New Haven, 1916.

subsequent years, it was not reached again before 1904 when the data end (Table A-1).[2]

A further indication of the relatively small and unspecialized nature of the industry is the fact that the National Machine Tool Builders Association was founded by seventeen firms as late as 1902, and the Association has published no industry data for the period before 1900. Finally, it was not until the 1914 Census of Manufactures that the federal government published separate data for industrial machinery output, including machine tools, but the report is far from complete. The earlier decennial Census reports on manufacturing have a section listed as machinery, but machine tools are not treated separately. The sector as reported includes such things as agricultural implements, sewing machines (including presumably the total output of Brown and Sharpe until at least the Census of 1880), pumps, engines, professional and scientific instruments, and an omnibus category of foundry and machine shop products, n.e.s.—by far the largest category of all.

This paper deals only with metal-cutting machines and includes no information on metal-forming types. A lathe or milling machine would be an example of the first type, a press or hammer would be an example of the second. Furthermore, the paper deals with general-purpose standard machines of the light variety. Neither machines made on special order for a particular job nor industry-specialized machines such as textile or mining machinery are included. The machines considered here are the versatile, primary machines used in the production of other machinery as well as in the production of such goods as sewing machines and typewriters, not generally considered to be machines. It has proved impossible to quantify the size of the special-order output of machine tools in the nineteenth century. Manufacture of such tools was apparently concentrated in Philadelphia, particularly in the William Sellers Company and in the group of firms eventually combined as the Niles-Bement-Pond Company.[3] All attempts to uncover any records of the early Philadelphia companies met with failure.

The period covered in this paper is 1861–1910. The beginning date was chosen because no reliable quantitative data were found for any earlier years. Hubbard, in a series of articles in the *American Machinist* about the early beginnings of machine tool manufacture in New England, lists an impressive number of persons and companies involved in machine

[2] There is, of course, a difference between sales and shipments, but the relative importance of machine tools in total sales is nonetheless represented accurately.

[3] Roe, *English and American*, pp. 249–260.

tool design and production before 1860.[4] Yet the impression gained is of a series of small undertakings to meet specific needs, such as government musket contracts, or construction of special machinery to meet individual industry demands. For example, a mechanic in a textile mill or a small shop might build a lathe for his own use, but there is no evidence in Hubbard's work that there were machine tool companies as such. Roe, although more concerned with technical developments in machine tool design than with quantitative measures of the industry, uses 1850 as the beginning date of the American machine tool industry. As subsidiary evidence, it might be noted that none of the charter companies of the National Machine Tool Builders Association existed in 1860, as far as can be determined from the various regional genealogies of the industry.

The primary source of the data used in the paper is company records. The best records, and the only ones for 1861–81, were obtained from the Brown and Sharpe Company for 1861–1905. The records list a total of 23,658 machine tools shipped by the company from September 1861 to June 1905.[5] Each shipment is recorded by type and size of machine, date of shipment, name and location of consignee, and price. Year-end financial statements of the same company were also obtained for 1869–1905. A second shipment series was obtained from the Bullard Company of Bridgeport, Connecticut, covering a total of 6,535 machines shipped between April 1881 and December 1912. Those records did not include price, but a separate price record found for 1895–1912 made possible calculation of dollar sales for the shorter period. Sales figures have also been obtained for the G. A. Gray Company, Cincinnati, for 1886–1910, and for the Cincinnati Shaper Company for 1899–1910. A 20 per cent sample of the shipment records of the two Cincinnati companies showing region of destination, by various time periods, is also available.[6] Finally, a series of the dollar value of new orders was obtained from the Warner and Swasey Company of Cleveland for 1880–1910, and a series of sales figures from the same company beginning in 1903. A total of twenty-one existing machine tool companies with roots extending back into the nineteenth century were communicated with in the study. All requests were met with offers of assistance, but all except the above-mentioned

[4] G. Hubbard, "Development of Machine Tools in New England," *American Machinist*, Vols. 59 and 60, 1923 and 1924.

[5] Shipments differ from production by the number of machines produced but retained for the company's use and by the net change in machine inventory. Data for shipments only were available.

[6] The information on the Cincinnati companies was made available to the author through the kindness of George A. Wing.

few reported that early records had been destroyed, frequently as a result of consolidation or reorganization of firms.[7]

The subsequent analysis in this paper is based, therefore, on the records of a relatively small number of firms. There is no way of telling how representative of the industry the sample is. We do know that Brown and Sharpe was an early technical leader in the machine tool field and one of the leading producers of light machine tools in New England. The Brown and Sharpe Company began in 1853 when Lucien Sharpe, who proved to be the businessman of the combination, was brought into the company formed in 1833 by David and Joseph R. Brown, father and son, to make and repair clocks. In 1850 Joseph Brown developed the first automatic linear dividing engine for graduating rules, a machine Roe mentions as still being in use in the shop in 1916. The next efforts were production of protractors and calipers with the vernier scale attached. Standards and accuracy of measurement continued to be an important concern of the firm—as they still are today—but, from the point of view of this paper, the developments must be considered peripheral to the main subject. The first machine tool produced for sale by the company was a turret screw machine of a general design well known at the time, sold in 1861 to the Providence Tool Company which had a contract to manufacture Springfield muskets for the government. Joseph Brown's significant contribution to machine tool design came in 1861-62, when he invented the universal milling machine. The first of these new machines was shipped in 1862, again to the Providence Tool Company.

Throughout the period covered by the available records, Brown and Sharpe concentrated on the production of light, standard machine tools, screw machines, grinding machines, and the universal milling machine. In this respect, it was apparently similar to Pratt and Whitney, whose product line was much the same in nature although more extensive in both kind and number of machines produced. Brown and Sharpe is therefore probably a good sample of the light machine tool operations in New England as a whole.

The Bridgeport Machine Tool Company, which was to become the Bullard Company, was established in 1880 as a producer of machine tools in Bridgeport, Connecticut, by E. P. Bullard. Bullard was a mechanic who had become a machine tool agent in New York City and, from his experience in selling tools, he recognized the need for a more accurate

[7] The greatest disappointment in this project was the discovery that the first volume of the shipment records of the Pratt and Whitney Company of West Hartford, Connecticut, covering the period up to about 1904 had been destroyed eighteen months before I wrote to the firm.

engine lathe than those currently available. He engaged a mechanic to produce the lathes in Bridgeport but, within a year, had taken full control of the operation. The first shipment of the new company was a total of twenty-five 16-foot by 5-inch engine lathes between April and June 1881, consigned to the Westinghouse Airbrake Company of Pittsburgh. In 1883, Bullard made a significant contribution to the technical progress of the machine tool art with the invention of a small boring mill capable of accurate production work. The new machine was publicized for the first time in 1883, but no shipments were made until 1885. With the movement into the boring mill and the larger engine lathe, the Bullard Company developed a product line of machines that were larger, as measured by average price per machine, than those developed by Brown and Sharpe.

There is no way of assessing the representativeness of the sample collected. The records of Brown and Sharpe are extremely valuable because it is fairly certain it was quantitatively a large firm and was certainly a leader in the technology of the light machine tool field. Bullard is also a valuable sample because, while not quantitatively so large a firm as Brown and Sharpe, its output encompassed the larger type of production machine tool. The evidence available for the Ohio companies is only meager and, while implications can be drawn from the information available, it will not support much analysis.

Little more can be said beyond affirming that the information gathered for this paper exceeds anything previously available, and that an effort has been made to track down as much relevant material as possible. What follows, therefore, while strictly speaking a quantitative study of selected firms, represents the growth pattern of the American type of production cutting machine tool through the first decade of this century.

Growth of Output

The literature on the history of the American machine tool industry never fails to point to the supreme importance of the machine tool in the development of what came to be called the American system of manufacture. There can be no doubt that mass production, the standardization of parts, and precision manufacturing all stemmed from advancing technology embodied in machine tools. What seems clear from the record, however, is that these accouterments of an industrial society came at a fairly late stage in the process of development and were associated with a particular change in output mix.

Perhaps the most impressive aspect of the quantitative records available is that the volume of shipments was so small (Table A-2). The first

machine tool was shipped by Brown and Sharpe in 1861. It was not, however, until 1875 that the cumulative total of machines shipped passed the 1,000 mark, and not until 1883 that it reached 2,000. Between September 1861 and June 1905, the records show that Brown and Sharpe shipped a total of 23,658 machine tools, but 12,447 of the total number, or 52.6 per cent, were shipped between January 1899 and June 1905. The Bullard Company began shipping machines in April 1881, but it was not until 1890 that the cumulative number of shipments passed the 1,000 mark. Up to the end of 1910, Bullard shipped a total of 6,162 machines, but 3,229 of the total number, or 52.4 per cent, were shipped between January 1901 and December 1910.

There is ample evidence that the acceleration in the rate of growth of commodity output which marked the initial period of industrial development in the United States began before the Civil War. Whether or not one wishes to call it the period of "take-off," following Rostow, it is clear from Gallman's figures that the high decade rates of growth shown for the period just before 1860 must have marked a sharp change from the rates existing in the early decades of the nineteenth century.[8] Gallman's figures also show evidence of a decline in the growth rates of commodity output, and particularly in the growth rate of value added by manufacturing, in the latter decades of the nineteenth century. As Gallman pointed out, his results are roughly consistent with the trend-cycle dating determined by Burns from his study of production trends, which shows a period of rapid increase of nonagricultural industrial output between 1875 and 1885 and again between 1895 and 1905.[9]

Table 1 presents rates of change calculated from the available long-term records of machine tool output along with selected rates of change derived from Gallman. The Gallman rates of change are based on single-year figures, while those for the machine tool shipments are three-year averages centered on the years available to Gallman. Presumably, therefore, the Gallman figures would show the influence of business cycles more sharply than the shipment figures do, but the differences are so clear that the conclusions drawn from the table are unlikely to be affected by cyclical variations in the underlying figures.

The conclusion derived from the table is that the light production machine tool was not quantitatively important in the period of American industrialization but became important at a later period. This conclusion

[8] R. E. Gallman, "Commodity Output, 1839–1899," *Trends in the American Economy in the Nineteenth Century*, Studies in Income and Wealth 23, Princeton for NBER, 1960, pp. 15–17.

[9] A. F. Burns, *Production Trends in the United States since 1870*, New York, NBER, 1934, pp. 215–220.

could result from the fact that only one company is considered. The explanation of the difference in the aggregate and single-company growth figures could merely reflect a sudden increase in the prominence of Brown and Sharpe, or a technical development that permitted a sharp increase in the output of the firm. Both explanations appear unlikely. Brown and Sharpe had a wide reputation as a machine tool producer, if its exhibition of tools at international expositions as early as 1869 is any indication.[10] Also, the second hypothesis seems unlikely in view of the fact that the company's product line, which represented inputs to its own productive process, shows no apparent marked technical change over time.

TABLE 1

RATES OF CHANGE IN MACHINE TOOL PRICES AND OUTPUT, SELECTED VARIABLES, DECENNIAL OR QUINQUENNIAL, 1864–69
(per cent)

Year	Value Added in 1879 Prices of Manufacturing (1)	Change in Value in 1879 Prices of Manufactured Producer Durables Output (2)	Change in Number of Brown and Sharpe Shipments of Machines		
			Total (3)	Domestic (4)	Foreign (5)
1864					
1869	26	72			
1874			25	4	
1879	82	67	25	35	-12
1884	90		50	121	67
1889	112	117	376	300	654
1894	71		229	201	400
1899	51	48	221	170	320

Source: Col. 1 from Gallman, "Commodity Output," Table 3, p. 24; col. 2 calculated from *Ibid.*, Table A-12, p. 65; cols. 3-5 from company records.

The more likely explanation is found in the relation between machine tool output and the industrial destination of the machines, which can be inferred from the major product of the buyer. The name of the buyer does not always appear in the available records showing the consignee of shipments. Where the consignee was an agent and only the agent's name was listed, it was impossible to determine the eventual destination of the machine. In other records, the name of the consignee gave no clue to the industry to which it belonged, although in some such cases the firm could be allocated by reference to other sources. Of a total of 22,478 machines shipped by Brown and Sharpe to December 1904, 8,499 or

[10] Brown and Sharpe published a catalogue in French in August 1867, and one in German in April 1868.

37.8 per cent were consigned to domestic and foreign agents or allocated to unknown buyers. Of this number, 4,469 or more than half were consigned to foreign agents. Of the total of 6,162 machines shipped by Bullard to December 1910, 2,498 or 40.5 per cent were consigned to domestic and foreign agents or allocated to unknown buyers. Of this number, 1,284 or more than half were consigned to foreign agents. The problem of the agent comes up again with respect to machine tool companies as consignees. We know, for example, that Pratt and Whitney established agencies in many parts of the United States fairly early in its history, and acted as agents for Brown and Sharpe as well. The very minor number of machines consigned to Pratt and Whitney indicates that, in spite of the affiliation, final consignee was specified on sales through the agent. There is no way of telling, however, how many local machine shops, especially those begun by Brown and Sharpe apprentices, might have acted as agents.

Table 2 presents quinquennial totals of part of the industrial distribution of shipments by Brown and Sharpe and by Bullard. There are two significant points shown by the table. The first is the clear association between the expanding output of machine tools and the growth of industries producing fairly complex and technically sophisticated final products. The bicycle, the cash register, and the electrical equipment industries, and government arsenals all placed substantial orders for machines after 1885. Second, the difference in the relative size of the machines in the Brown and Sharpe and Bullard product lines shows up in the table. Bullard shipped no machines to companies producing cash registers between 1881 and 1910, only eighteen machines to sewing machine companies, and only seven machines to bicycle companies. On the other hand, the percentage of total Bullard shipments consigned to iron foundries and iron and steel mills was six times the corresponding percentage for Brown and Sharpe. Sales by the two companies to automobile producers show an interesting difference. Bullard shipped its first machine to an automobile company in 1901 by which time Brown and Sharpe had shipped 101 machines but, as the automobile increased in size and complexity, heavy tools became more important as inputs, and shipments by Bullard increased markedly.

A machine tool of the type considered here is a fairly versatile input. It is true that the machines produced before 1910 were specific in the types of operations they could perform; an engine lathe, for example, was quite limited in the kinds of operations it could be set up to accomplish at one time, but these machines could be used to produce many different products. The reasonable conclusion seems to be that, until after 1884

TABLE 2

INDUSTRIAL DISTRIBUTION OF MACHINE TOOL OUTPUT, QUINQUENNIAL, 1861-1909
(number of machines)

Purchasing Industry	1861–64[a]	1865–69	1870–74	1875–79	1880–84[b]	1885–89	1890–94	1895–99	1900–04	1905–09
				A. SOLD BY BROWN AND SHARPE						
Machine tools	16	22	16	8	63	90	194	439	649	
Rifles and ammunition	100	11	41	10	5	9	62	85	259	
Sewing and shoe machines	22	62	135	35	120	88	93	140	253	
Calculators and cash registers	0	0	0	0	9	13	101	183	716	
Professional and scientific instruments[c]	0	10	6	9	35	30	65	144	282	
Government arsenals	3	14	14	1	6	379	113	409	601	
Electric equipment	0	0	0	3	60	49	157	538	797	
Bicycles	0	0	0	0	0	27	32	267	78	
Automobiles	0	0	0	0	0	0	0	55	268	
Railroads and R.R. equipment	4	9	19	11	69	71	95	117	182	
Sum of cols. as per cent of total machines[d]	95.4	80.0	68.5	61.1	71.3	67.8	58.2	63.3	65.4	
				B. SOLD BY BULLARD						
Machine tools					36	87	99	66	101	91
Railroads and R.R. equipment					112	65	104	77	207	212
Iron and steel					3	31	85	81	65	91
Electric equipment					4	53	54	52	192	167
Government arsenals					1	10	49	31	24	17
Bicycles					0	0	0	0	5	2
Automobiles					0	0	0	0	19	88
Sum of cols. as per cent of total machines[d]					76.1	70.3	68.2	74.2	71.9	65.6

Source: Company records.

[a]September 1861 to December 1864, Brown and Sharpe.

[b]April 1881 to December 1884, Bullard.

[c]Includes companies making watches, clocks, cameras, optical equipment, and dental equipment.

[d]These are column totals as a percentage of the total number of machines that could be allocated by user.

or more noticeably after 1895, the demand for light machine tools was relatively limited. The large demand for machine tools beginning at the turn of the century can be associated with the development of a new technology, and with the beginnings of what Rostow has called the period of "high mass consumption."

Market for Machine Tools

While the volume of shipments from machine tool companies was apparently quite modest until nearly the end of the nineteenth century, the market was anything but local. During the Civil War the market was dominated by domestic demands from armament makers. Between September 1861 and the end of 1864, Brown and Sharpe shipped a total of 201 machines, 100 of them to armament makers in New England. As soon as the war demand ended, the market area expanded considerably. The first shipments by Brown and Sharpe to foreign customers were made in 1865, when two machines were shipped to Canada and two to France. From 1865 on, the foreign market accounted for a significant proportion of Brown and Sharpe shipments, never accounting for less than 10 per cent of the total in any one year, and in some years rising to over 50 per cent. For the Bullard Company, foreign shipments were not as significant a proportion of the total until after 1896 but, of the ninety machines shipped in the first year, 1881, two were consigned to foreign customers. In the fifteen years between 1881 and 1895, there were only five years when no foreign shipments were made, and a total of thirty-seven machines were shipped abroad. In 1896, 25.9 per cent of the machines shipped went to foreign buyers, and in the four years 1897–1900 the proportion was between 50 and 60 per cent. In the decade 1901–10 an average of 23 per cent of Bullard shipments was consigned to foreign customers (Table A-3).

A sample of the shipments of the two Cincinnati companies shows that the New England toolmakers did not monopolize the foreign trade. A 20 per cent sample of the shipments by the G. A. Gray Company between 1884 and 1907 (sample size, 799 machines) shows 165 machines, or 20.8 per cent of the total, consigned to foreign customers. The same type of sample taken from the records of the Cincinnati Shaper Company between 1899 and 1907 (sample size, 554 machines) shows that 110 machines, or 19.9 per cent of the total, were shipped abroad. Finally the sales records of the Warner and Swasey Company of Cleveland show an average

share of foreign in total sales of 18.8 per cent between 1903 and 1910.

As one would expect, northwest Europe dominated the foreign market. The number of machines shipped by Brown and Sharpe and by Bullard to foreign regions, by quinquennia, is shown in Table 3. On the reasonable

TABLE 3

FOREIGN SHIPMENTS OF MACHINE TOOLS, BY REGION OF DESTINATION, QUINQUENNIAL, 1861-1909
(number of machines)

Period	Northwest Europe	South Europe[a]	Russia and East Europe[b]	Canada	Central and South America	Australia	Asia	Africa
			A. BROWN AND SHARPE					
1861-64[c]	0	0	0	0	0	0	0	0
1865-69	27	3	1	16	0	0	0	0
1870-74	60	10	5	34	0	0	0	0
1875-79	55	0	0	5	3	0	0	0
1880-84	84	0	2	29	7	1	2	0
1885-89	633	0	2	13	5	2	0	0
1890-94	431	6	38	25	8	7	0	7
1895-99	2,560	43	257	39	16	7	16	2
1900-04	2,349	49	127	140	18	2	331	5
Percentage distribution of totals	82.9	1.5	5.8	4.0	0.8	0.2	4.7	0.2
			B. BULLARD					
1881-84[d]	7	0	0	1	1	0	0	0
1885-89	13	0	0	0	0	0	0	0
1890-94	7	0	0	4	0	0	0	0
1895-99	446	0	8	2	1	0	0	0
1900-04	394	3	1	30	1	0	2	0
1905-09	341	20	9	29	4	1	9	0
Percentage distribution of totals	90.6	1.7	1.3	4.9	0.5	0.0	1.2	0.0

Source: Company records.

[a] Italy, Spain, Portugal, Greece, Turkey.

[b] Poland, Rumania, Bulgaria.

[c] Sept. 1861 to Dec. 1864.

[d] Apr. 1881 to Dec. 1884.

assumption that foreign companies purchasing American machine tools were not tied to particular American producers, this table can be taken as representative of the regional distribution of foreign shipments by the American machine tool industry as a whole. There are differences between the two panels of the table. The Brown and Sharpe figures show a smaller proportion of total foreign shipments to northwest Europe and a larger proportion to Russia (including eastern Europe) and Asia than the

Bullard figures do. The differences are accounted for by relatively large shipments by Brown and Sharpe to government arsenals in Russia between 1895 and 1901 (over 300 machines) and to Japanese government arsenals and shipyards in 1904 (260 machines). Since the Bullard line of products was not suitable for armaments manufacture at that time, the company did not share the market.

That northwest Europe was the major foreign market for shipments is, of course, not surprising. Nor is the distribution by country of destination within Europe. Table 4 presents the distribution of shipments to northwest

TABLE 4

SHIPMENTS BY BROWN AND SHARPE TO NORTHWEST EUROPE, QUINQUENNIAL, 1865-1904
(number of machines)

Period	United Kingdom	France	Germany	Sweden, Denmark	Belgium, Netherlands	Switzerland, Austria
1865-69	4	12	4	0	0	0
1870-74	28	1	17	13	0	1
1875-79	23	20	11	0	1	0
1880-84	56	7	20	1	0	0
1885-89	181	352	67	23	3	7
1890-94	182	60	92	47	14	36
1895-99	975	511	621	243	80	130
1900-04	1,106	587	323	121	77	135

Source: Company records.

Europe, by country of destination, for Brown and Sharpe only.[11] The United Kingdom was clearly the largest single purchaser of machines from Brown and Sharpe, not only in total but also in all subperiods except 1865–69 and 1885–89. The large volume of shipments to France in the latter quinquennium is made up primarily of shipments to French government arsenals, which received nearly 200 machines between 1886 and 1888.

In the total number of machines shipped, France was the second largest customer and Germany the third largest. Most, although not all, of the difference is accounted for by the large shipment to French arsenals noted above. The time distribution of machines to other regions generally coincides with what is known about their periods of industrialization.

[11] In Tables 3 and 4, the distribution was derived from records that generally list only one consignee. Thus, a London or Antwerp agent might subsequently ship a machine consigned to him to another region or country. In view of the number of agents scattered throughout Europe, this possibility is unlikely to affect the distribution appreciably.

Expectably, the destination of the machine shipments moved across Europe in general conformity with the eastward progress of the industrial revolution.

The same sort of geographic distribution of machine shipments based on the level of industrial activity in a region is evident in Table 5, where

TABLE 5

SHIPMENTS TO UNITED STATES REGIONS, QUINQUENNIAL, 1861-1909
(number of machines)

Period	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
				A. BROWN AND SHARPE					
1861-64[a]	112	81	3	0	5	0	0	0	0
1865-69	95	122	15	0	5	0	0	0	2
1870-74	161	208	20	2	0	2	1	0	4
1875-79	69	90	35	4	2	0	0	0	8
1880-84	272	419	138	17	24	4	2	0	9
1885-89	396	491	221	26	52	8	6	3	7
1890-94	699	784	373	26	90	18	3	4	10
1895-99	1,252	1,270	853	35	93	23	7	10	23
1900-04	1,840	2,219	1,695	151	250	16	12	19	83
Percentage distribution of totals	32.6	37.9	22.4	1.7	3.5	0.5	0.2	0.2	1.0
				B. BULLARD					
1881-84[b]	90	214	20	0	3	0	3	0	0
1885-89	206	276	85	0	14	1	1	0	1
1890-94	173	351	37	0	109[c]	0	0	1	3
1895-99	126	296	14	4	49	0	0	0	47
1900-04	188	521	241	20	69	8	11	4	25
1905-09	206	500	421	36	36	19	14	6	31
Percentage distribution of totals	22.1	48.3	18.3	1.3	6.3	0.6	0.4	0.2	2.4

Source: Company records.

[a]September 1861 to December 1864.

[b]April 1881 to December 1884.

[c]Between 1890 and 1892, 46 machines were shipped to the Navy Department in the District of Columbia.

the distribution of shipments to United States regions (Census definition) is given for Brown and Sharpe and for Bullard. The dominant position of the middle Atlantic region is clear from the table. In all but the first subperiod 1861–64, that region received more machines than any other from both companies. The New England and east north central regions received some machines in all subperiods, and while neither was as

quantitatively important as the middle Atlantic region, the inference certainly is that the domestic market for the tools of these New England companies was widespread. The transportation costs—probably fairly substantial, at least in the early period—did not limit Brown and Sharpe to a local market.

That transportation cost was not a strong deterrent is shown most strikingly by the increase in the volume of shipments to the east north central region after 1880. As Roe has pointed out, "prior to 1880 practically all of the tool building in the United States was done east of the Alleghenies," but that "good tool building appeared in Ohio in the early eighties, and within the ten years its competition was felt by eastern tool builders." [12] It is clear, however, that growth of manufacturing and of a machine tool industry in the Ohio Valley had only good effects upon the New England companies. Increased industrial activity meant increased machine tool inputs, and New England production machine tools were among the best available.

The table does indicate that, whereas from the subperiod 1885–89 on Brown and Sharpe shipped machines to all regions, Bullard did not consistently ship to all regions until the period 1900–04. That the difference resulted from the higher transportation costs incurred by the larger and heavier Bullard machines is unlikely. The more likely explanation is that the heavier production machine is not required as an input until a region reaches a certain threshold of industrial sophistication.

The information available from the Cincinnati firms shows that they also enjoyed a wide geographic market for their output. The 20 per cent sample of the shipments of G. A. Gray Company for the period 1884–1907 contains 631 domestic shipments. The percentage distribution of the destination of the shipments shows that 8.2 per cent went to New England, 26.9 per cent to the East,[13] 53.2 per cent to the north central region,[14] 4.6 per cent to the South, and 7.0 per cent to the West. The percentage distribution of the 444 domestic machine shipments in the 20 per cent sample of the Cincinnati Shaper Company between 1899 and 1907 shows that 5.2 per cent went to New England, 45.7 per cent to the East, 26.8 per cent to the north central region, 10.4 per cent to the South, and 11.9 per cent to the West. It appears from these figures that Roe's statement that the Ohio companies competed with the New England firms was correct. It is also true that such competition, carried on in a rapidly expanding market, had beneficial effects on the firms in both regions.

[12] Roe, *English and American*, p. 261.
[13] Defined as New York, New Jersey, Pennsylvania, Maryland, Delaware.
[14] Defined as Ohio, Indiana, Illinois, Wisconsin, Michigan, Minnesota.

The relative size of the firms in both regions should be noted. Roe mentions that the Gray Company started in 1883 to build lathes, but soon specialized on planers and "is now [1916] one of the foremost firms in the country specializing in this type of tool." [15] Yet the 20 per cent sample taken from Gray's shipment records shows a sample size of only 987 machines shipped between 1884 and 1915, 767 of which were domestic shipments.

Feast or Famine Industry

Discussions of the machine tool industry mention in some form or other the fact that fluctuations in output of the industry tend to be much wider than fluctuations in general industrial output or in the index of economic activity. It might be argued, however, that this characteristic of the machine tool industry is part of a well-known phenomenon of an industrial economy which has acquired and is using a large stock of producer durable equipment. During a period of industrialization, sufficient momentum might be generated by new, rapidly growing industries so that the output of machine tools is little affected by fluctuations in general commodity output.

Whatever the theoretical merits of such a hypothesis, it is clear from the available records of machine tool output and sales (Table A-2) that the firms were subject to substantial fluctuations in demand. Unfortunately, the National Bureau reference cycle chronology does not give measures of the severity of cycles for the period under review here, and it is impossible therefore to say whether machine tool demand fluctuated more widely than aggregate demand.

Comparison of the National Bureau reference cycle chronology with the measures of machine tool output shows three periods of nonconformity.[16] The reference cycle peak of 1869 and trough of 1870, the peak of 1887 and trough of 1888, and the peak of 1895 and trough of 1896 are not reflected clearly in the output measures. For the first period, 1869-70, only the output series for Brown and Sharpe is available, and so perhaps no great importance should be attached to the nonconformity. For the second period, 1887-88, four series are available and only the new-orders series of Warner and Swasey shows a contraction. For the third period, 1895-96, four series are available and only the Gray Company sales series shows a contraction. Both 1886–90 and 1895–99 were periods

[15] Roe, *English and American*, p. 273.

[16] A. F. Burns and W. C. Mitchell, *Measuring Business Cycles*, New York, NBER, 1946, p. 78.

of substantial increase in the level of machine tool output. The nonconformity with reference cycle dating might then serve as evidence that, during periods of vigorous demand associated perhaps with rapid technical change, the output of machine tools is unaffected by cyclical contractions in aggregate demand.

The evidence almost disappears, however, when the output series are separated into domestic and foreign shipments, which is possible with the Brown and Sharpe and the Bullard data (Table A-3). There is no contraction in the Brown and Sharpe domestic shipment series in 1869-70, or in the Bullard domestic shipment series in 1887-88. But there is a clear contraction in the Brown and Sharpe domestic shipment series in 1887-88, and the domestic shipment series of both companies show a contraction after 1895, Bullard in 1897, and Brown and Sharpe in 1896-97.

The differences in the cyclical behavior of the total and domestic shipment series is perhaps to be expected from the differences in the reference cycle dates in the United States, France, Great Britain, and Germany. There is very little evidence of an inverse cycle in domestic and foreign shipments, but the foreign shipments of Brown and Sharpe reached a peak in 1888, and there was a strong foreign demand for both Brown and Sharpe and Bullard output between 1895 and 1901 which submerged the domestic contraction of 1895-96.

Summary

The data collected for this paper are undoubtedly far from satisfactory as a basis for an analysis of the nineteenth century machine tool industry, but company records are the only source from which a quantitative record of the industry can be established.

The data assembled suggest that the demand for light, metal-cutting machine tools was relatively small during the initial period of industrialization, when technical development was embodied in fairly large and crude systems. Sewing machine manufacturers were a steady component of the demand for Brown and Sharpe machines back to 1861. It was not until the 1890's, however, that manufacturers of electrical equipment, calculators, cash registers, and bicycles provided a rapidly expanding market for light tools.

The data also show that the American machine tool industry enjoyed a truly worldwide market during the nineteenth century. Much has been written about the technical superiority of the American machines during the period, and certainly the records indicate that quality was recognized by expanding export markets in six continents.

For this particular industry, 1910—the end date of the analysis here—is significant because it can serve as a dividing line in the history of machine tools. After 1910, the assembly line called for more specialized and special-order machines than before, and faster cutting speeds and heavier machines were in demand. The automobile industry alone created a revolution in machine tool building.

Appendix

In addition to background data for the text tables, the appendix presents some additional information collected from machine tool companies during the study but not used directly in the earlier pages.

Table A-1 presents information relating to Brown and Sharpe only. The figures on total sales were taken from annual financial statements, while the amount of sewing machine work and "other work done" came from other records. The same basic data must have been used in both records, because the breakdown of the sales figures adds to total sales. Other work done is not further specified, but it must have included machine tool sales and probably also repair work and miscellaneous products. The shipment records mention production of core ovens, foundry rattlers, and soda kettles, which would serve to utilize the foundry facilities of the company. Also noted are grindstones and grindstone troughs which would be the forerunners of the grinding machines, an important part of machinery shipments after the late 1870's. Between 1873 and 1881, the company produced 199 cylindrical sewing machines or seamers with an aggregate value of $26,891 that were shipped to domestic and British print works and bleacheries. No description of this machine was found, but the name suggests that Brown and Sharpe's experience in sewing machine production enabled it to produce the machine as a stopgap measure during the depression following 1873.

The profit series in Table A-1 is taken from a set of financial statements found in the company's files. The statements apparently were put together as a hybrid balance sheet and income statement for the information of the owners of the business to show the position of the firm on January 1 of each year. They were probably used by the owners to determine the total dividends to be paid each year.

To arrive at the profit figure, a figure of capital value on January 1 was first derived. Capital value was computed as the sum of cash, notes, accounts, value of land, plant, and equipment, and what was called "stock," which may or may not include the inventory of finished and unfinished goods. The profit during the year (column 6) was derived by taking the difference between two successive capital values, adding the

dividends taken out during the year, and subtracting the amount received from Darling, Brown, and Sharpe, the precision instrument subsidiary until 1893 when Darling's share was purchased by the parent company. Causes of the fluctuations in what is called profits could not be determined by examination of the records. The substantial figures for the period 1869–73 appear to be largely the result of an upward valuation of the land, buildings, and tools owned by the company, and the losses of 1874 and 1875 of a downward revaluation of buildings and fixtures.

The financial statements are clearly unacceptable in terms of good accounting practice. Business decisions probably were made in part on the basis of them, however, and on that ground the profit series is relevant information. That other factors also influenced decisions is clear from the lack of correspondence between the dividend series and the profit series. Dividends do not move in the same direction as profits in as many as half of the years shown.

TABLE A-1

SUMMARY OF FINANCIAL STATEMENTS, BROWN AND SHARPE, 1863-1905
(dollars, current prices)

Year	Total Sales (1)	Sewing Machine Work (2)	Other Work Done (3)	Machine Tool Shipments (4)	Dividends Paid (5)	Profit or Loss (6)
1861[a]				3,590		
1862				17,771		
1863	89,827	59,728	30,099	15,294		
1864	168,437	108,130	60,307	37,436		
1865	159,059	109,649	49,410	29,248		
1866	254,874	201,607	53,267	33,459		
1867	231,547	194,387	37,159	28,018		
1868	210,720	155,940	54,780	40,930	24,000	
1869	292,571	215,832	76,739	52,410	27,200	165,225
1870	331,366	261,273	70,092	54,350	32,000	128,348
1871	393,781	297,863	95,918	74,841	32,000	158,477
1872	288,138	193,057	95,080	75,094	32,000	70,984
1873	225,331	131,111	94,219	77,493	16,000	85,647
1874	156,309	111,823	44,486	23,463	--	-49,472
1875	188,793	137,910	50,884	20,005	--	-781
1876	179,330	134,534	44,977	33,613	--	10,928
1877	158,676	104,109	54,567	36,450	67,875	14,157
1878	173,450	124,153	49,297	20,346	27,150	35,167
1879	243,524	164,867	78,656	40,890	76,925	70,513
1880	334,866	183,806	151,061	74,504	54,300	78,063
1881	436,036	190,774	245,262	122,872	--	132,124
1882	495,993	187,173	308,811	124,010	36,200	150,526
1883	433,903	162,075	271,827	120,230	76,925	136,470
1884	440,698	194,847	245,850	95,565	76,925	163,992
1885	401,001	197,751	203,250	66,949	31,675	78,999
1886	557,195	160,689	396,506	162,400	72,400	124,176
1887	592,246	149,261	442,985	189,305	22,625	139,915
1888	772,439	237,386	535,052	243,843	27,150	199,421
1889	881,455	183,530	697,925	298,580	45,250	156,254
1890	960,840	117,176	843,665	312,322	40,725	222,265
1891	881,055	105,182	775,874	247,236	49,775	174,870
1892	892,481	140,598	751,883	259,698	63,350	208,525
1893	836,695	147,696	689,000	239,660	36,200	33,179
1894	701,395			185,455	27,150	103,824
1895	1,029,160			378,942	54,300	221,587
1896	1,098,710			467,997	45,250	174,657
1897	1,270,082			612,216	36,200	501,272
1898	1,541,354			799,885	54,300	421,254
1899	2,070,859			1,015,093	99,550	522,434
1900	1,963,382			966,341	72,400	492,953
1901	1,961,215			845,374	72,400	526,888
1902	2,426,404			1,197,145	90,500	502,461
1903	2,540,331			1,166,546	181,000	359,256
1904	2,339,047			1,035,161	181,000	830,022
1905	3,604,377				208,150	

Source: Company records. See text for derivation of col. 6.
Note: Details may not add to total because of rounding.

[a]September to December 1861.

TABLE A-2

MEASURES OF OUTPUT OF SELECTED MACHINE TOOL COMPANIES, 1861-1910

Year	Brown and Sharpe Shipments (number) (1)	Bullard Shipments		G.A. Gray Sales (dollars) (4)	Cincinnati Shaper, Sales (dollars) (5)	Warner and Swasey New Orders (dollars) (6)	Total Output, Metal-Cutting Tools[a] (dollars) (7)
		Number (2)	Dollars (3)				
1861	17[b]						
1862	64						
1863	53						
1864	67						
1865	45						
1866	49						
1867	42						
1868	63						
1869	85						
1870	95						
1871	124						
1872	111						
1873	133						
1874	44						
1875	31						
1876	57						
1877	63						
1878	37						
1879	83						
1880	184					2,210[c]	
1881	229	90[d]				28,403	
1882	207	96				36,042	
1883	213	89				38,521	
1884	177	64				44,712	
1885	135	62				40,846	
1886	331	107		41,416		53,294	
1887	374	123		80,552		118,656	
1888	457	135		91,811		59,610	
1889	568	170		113,177		111,705	
1890	574	192		176,708		118,438	
1891	500	155		169,603		163,778	
1892	541	169		161,453		85,764	
1893	522	113		86,290		122,584	
1894	392	56		58,590		73,329	
1895	815	96	116,476	123,382		155,120	
1896	1,015	135	121,150	111,349		280,488	
1897	1,206	155	177,326	134,159		300,544	
1898	1,508	273	499,620	185,906		313,813	
1899	1,962	334	396,618	288,561	42,000	290,893	
1900	1,666	319	422,631	362,510	84,000	334,663	
1901	1,476	314	440,760	242,159	84,000	338,469	17,900,000
1902	2,126	362	544,826	330,659	137,000	328,413	22,800,000
1903	2,152	358	537,359	320,774	152,000	327,044	23,700,000
1904	1,885	167	219,140	169,952	97,000	200,804	18,300,000
1905	1,180	383	509,408	294,800	158,000	496,110	28,700,000
1906		469	733,908	266,098	139,000	756,521	36,400,000
1907		444	719,082	339,776	182,000	546,879	41,300,000
1908		108	185,868	89,044	114,000	309,408	16,800,000
1909		278	510,549	168,601	187,000	990,502	33,500,000
1910		346	694,337	313,352	240,000	739,429	44,300,000

Source: Cols. 1-6 from company records; col. 7 from National Machine Tool Builders Association, Washington, release F-A40a, Feb. 21, 1962.

[a]These figures are said by the NMTBA to include more than 90 per cent of total industry shipments, to exclude repair work, and to include parts shipped with machines.

[b]September to December 1861.

[c]August to December 1880.

[d]April to December 1881.

TABLE A-3

DOMESTIC AND FOREIGN DESTINATION OF OUTPUT, BROWN AND SHARPE AND BULLARD, 1861-1910

Year	Brown and Sharpe Shipments			Bullard Shipments		
	Domestic (number) (1)	Foreign (number) (2)	Foreign as Per Cent of Total (3)	Domestic (number) (4)	Foreign (number) (5)	Foreign as Per Cent of Total (6)
1861[a]	17	0	0.0			
1862	64	0	0.0			
1863	53	0	0.0			
1864	67	0	0.0			
1865	41	4	9.9			
1866	43	6	12.2			
1867	31	11	26.2			
1868	55	8	12.7			
1869	67	18	21.2			
1870	72	23	24.2			
1871	100	24	19.4			
1872	87	24	21.6			
1873	107	26	19.5			
1874	32	12	27.3			
1875	28	3	9.7			
1876	36	21	36.8			
1877	51	12	19.0			
1878	22	15	40.5			
1879	71	12	14.5			
1880	169	15	8.2			
1881	208	21	9.2	88[b]	2[b]	2.2
1882	174	33	15.9	90	6	6.2
1883	182	31	14.6	89	0	0
1884	152	25	14.1	63	1	1.6
1885	115	20	14.8	62	0	0
1886	200	131	39.6	106	1	0.9
1887	284	90	24.1	113	10	8.1
1888	241	216	47.2	135	0	0
1889	370	198	34.9	168	2	1.2
1890	445	129	22.5	188	4	2.1
1891	396	104	20.7	149	6	3.8
1892	450	91	16.8	168	1	0.6
1893	434	88	16.9	113	0	0
1894	282	110	28.1	56	0	0
1895	638	177	21.7	92	4	4.2
1896	560	455	44.8	100	35	25.9
1897	444	762	63.2	64	91	58.7
1898	719	789	52.3	129	144	52.7
1899	1,205	757	38.6	151	183	54.8
1900	928	738	44.3	143	176	55.2
1901	1,123	353	23.9	216	98	31.2
1902	1,669	457	21.5	330	32	8.8
1903	1,593	559	26.0	283	76	21.2
1904	972	913	48.4	115	52	31.1
1905				307	66	17.7
1906				332	137	29.2
1907				293	152	34.2
1908				82	26	24.1
1909				245	33	11.9
1910				273	73	21.1

Source: Cols. 1, 2, 4, and 5--from company records; col. 3--col. 2 as per cent of col. 1, Table A-2; col. 6--col. 5 as per cent of col. 2, Table A-2.

[a]September to December 1861. [b]April to December 1881.

COMMENT ON ROBERTSON AND McDOUGALL

W. Paul Strassman, Michigan State University

It is basic to machine tool technology that almost any object can be polished off or hammered out in remarkably dissimilar ways. So it is with these papers. Duncan McDougall insists that a quantitative record can only be exacted from company accounts and with unflinching consistency limits his observations to the data. Ross Robertson supplements company accounts with information from trade publications and government sources and aims at constructing estimates of the real national output.

Gratitude is due to Robertson for his useful appraisal of the sources of information he encountered and the difficulties of interpretation. I suspect that his estimates of metalworking machinery output for 1900–20 will have a greater durability than those of the machinery made during that period. I have only one question about his 1900–20 calculations. Why is the wholesale price index for all commodities better for adjusting 1900–13 prices than the Cincinnati metalworking machinery price index of George Wing? I would have expected Robertson to splice the American Appraisal Company's index to Wing's. Cincinnati prices went up three times as fast as the adjusted wholesale price index during 1900–14, 32 per cent compared with 10 per cent. But they rose only 21 per cent faster than the American Appraisal Company's index during 1914–20, or 188 per cent compared with 156 per cent.

The patterns McDougall found in the accounts of Brown and Sharpe and Bullard suggest once more that what seems plausible with casual hindsight is not necessarily what happened in history. Of course, once it is established that light machine tools were not quantitatively important until after the main push of industrialization, explanations for the lag come cheaper than September tomatoes, and each of us can provide his own. Since it is difficult to quarrel with what he documents so well, I have decided to pick mostly on things I imagine McDougall might have added.

But first I wonder if the late, accelerated importance of machine tools might not be understated by limiting the analysis to "general-purpose standard machines," as McDougall has. If special-purpose machines were developed after standard machines and then spread partly at the expense of standard machines, their omission means underestimating the trend. The more specialized users there are, the greater the chance of developing a special tool for them. Indeed, I was struck by McDougall's

Table 2 which shows Brown and Sharpe supplying nine industries after 1900 compared with four during the Civil War; and yet the four had accounted for 95.4 per cent of output compared with 65.4 per cent for the nine. A quarter of this 65.4 per cent, moreover, consisted of those diversified clusters, electrical manufacturers and professional and scientific instruments, which includes watches, cameras, and dental equipment, hardly a homogeneous outlet. According to the Census of 1905, the following types of machine tools accounted for only 66.3 per cent of production: lathes of all types; boring and drilling machines; milling machines; planers; stamping, flanging, and forging machines; and punching and shearing machines (*Bulletin 67*, pp. 9–13). Presumably some of these and much of the other third were special-purpose machines. Can one ignore the trend toward specialized machines for making gears, files, chains, and dozens of other products and components?

On the other hand, it may be that the advantages of copying declined during these decades, so that omitting copying means comparatively greater understatement of the earlier years, thus suggesting a higher rate of growth than the actual one. As the years passed, the machine tool producers accumulated enough tricks and specialized tool-building tools to discourage small-scale copying. During the Second World War, in Latin America and India a few metalworking shops likewise made lathes and planers for themselves but went back to importing afterward.

Speaking of Latin America, I was struck by Table 3 which shows that almost 12 per cent of Brown and Sharpe's exports after 1900 went to Latin America, Asia, and Africa. Were there buyers other than arsenals, shipyards, and sewing machine factories? From an industry as strategic as machine tools much can be learned about industrial development in other sectors. By the same token, much can be learned about machine tool production from the records of companies making sewing machines, electric motors, and the like, for example, from their changing inventories of machinery. I believe that this is one source not yet tapped. It is obvious how valuable it would be to know the changing durability of machine tools, and an approximation of the stock available in given years compared with the annual additions.

Finally, I should like to ask McDougall if anything can be done with the price per general-purpose lathe or milling machine? Do the accounts permit an estimate of how prices changed compared with cutting speed and capacity? If prices are available, perhaps an engineer could estimate "best-practice production functions" from surviving catalogues and other specifications.

Sources of Productivity Change